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Summary

In this study, we explored the long-term temporal (~ 40 years) pattern in functional structure of fish and benthic macrofauna in three Baltic Sea coastal areas with different environmental conditions located in Kattegat (Vendelsö area), the Baltic Proper (Kvädöfjärden area) and the Bothnian Sea (Forsmark area). Building on previous long-term studies on changes in taxonomic structure, we assembled trait information on six traits spanning morphology, life history and behaviour for over 200 macrofaunal taxa and six traits describing diet, habitat and productivity for over 52 fish taxa. To assess functional changes we analysed key functional indices as well as composition. Functional community trends were also related to environmental variables measured on a local and regional scale (water temperature and salinity). We highlight the coupling of these two ecosystem components (benthos and fish) and discuss the applicability of functional indices for the understanding of long-term community changes.

Introduction

Our understanding of changes in biodiversity has greatly improved by shifting the focus from primarily species richness as the measure of diversity to functional characteristics and the identity of species (Diaz & Cabido 2001). Still limiting our progress is the focus on single trophic levels or specific taxonomic groups as the setting in which we study diversity change (Thebault and Loreau 2003, Reiss et al. 2009). Another aspect that impedes our ability to understand and predict changes in ecosystems is our lack of knowledge about temporal variability of functional properties. Marine systems exhibit temporal change, both naturally and anthropogenically, the latter either indirectly through climate change or direct human pressures (Frid et al. 2011). Moreover, it is well known that temporal changes can appear as aperiodic shifts in community composition or long term changes (Möllman et al. 2011) and by that the potential for functioning (Frid et al. 2011, Neumann & Kröncke 2011, Törnroos & Bonsdorff 2012). It is hypothesized that such changes over time and across trophic levels also have the potential to change the delivery of goods and services (e.g. fisheries) (Raffaelli & Frid 2010). However, there is a lack of studies investigating functional changes across multiple trophic levels. Thus our general objective is to assess whether there are interlinked temporal (long-term, about 40 years) patters in the functional (trait) structure of fish and macrofauna in three coastal areas differing in environmental regime. We focus on the coastal ecosystem as this is known to be taxonomically and functionally rich, temporally variable, thereby providing an ideal model system for assessing long-term trends in functional diversity and richness within trophic levels/taxonomic groups and connections between food web compartments such as fish and benthos.

Materials and methods

Building on two previous studies on long-term changes in the taxonomic structure of fish (Olsson et al. 2012, all three study areas) and macrozoobenthos (Olsson et al. 2013, two of the three areas), we have

compiled new data for both fish (CPUE) and macrofauna (abundance, m^{-2}) spanning, in all but one area, up until 2013. We have in addition included macrofaunal data from Kattegat sampled in the vicinity of the fish-sampling site. The longest time series for fish and benthos started in 1971. Areas were analysed separately and a division between the warm (august) and cold (October/April) period was also considered for fish. To determine functional richness (FRic), evenness (FEve), dispersion (FDis) and a community-weighted mean (CWM), we included six traits for both fish and benthos. Functional analyses were run in the "FD" package (Laliberté & Shipley 2013) in R (R Core Team 2013). To investigate changes over time and statistically significant shifts in the functional indices, we applied change-point analysis in the "changepoint" package (Killick & Eckley 2014). To investigate the changes in functional composition PERMANOVA and SIMPER analysis were conducted using the "Vegan" (Oksanen et al. 2015) package. Future analyses include correlation analysis to determine linkages between fish and benthos functional composition as well as relationship between long-term changes in functional properties and environmental variables using generalized additive models (GAM).

Results and discussion

Preliminary results show an increase in fish species richness over time, especially in the cold season for all three areas, however the pattern is non-linear for the warm season. Macrofaunal species richness in Bothnian Sea and Baltic Proper showed little change over time. Based on the previous studies changes in both fish and macrofaunal composition occurred at the same time in the areas (late 1970s and 1980s and early 1990s). We found similar timing of functional changes for fish in the warm period but less pronounced for the cold season. In addition functional changes also occurred in the late 2000 in all areas for FRic and FEve. In general, although FRic increased in the areas, FDis (takes density into consideration) decreased or did not change, meaning an increase in species number did not increase the functional (trait) similarity of the community. Functional changes in macrofauna (Bothnian Sea and Baltic Proper) were not as evident as the changes in species composition found previously. Changes in functional (trait) composition over time were also observed for fish and macrofauna.

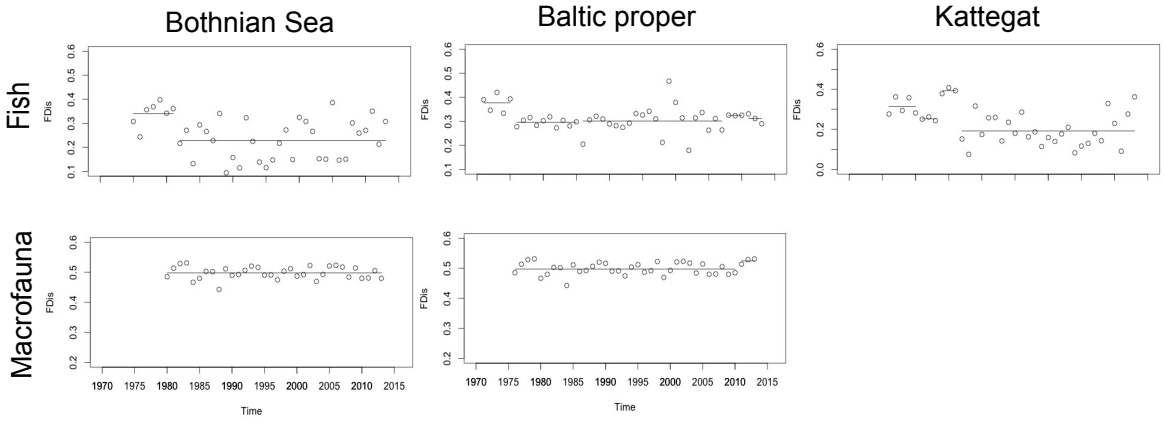

Fig. 1. Time series and change-point analysis of Functional dispersion (FDis) for fish and macrofauna from the three areas (macrofauna only two areas) sampled in the warm season (August). Change-point analysis based on mean and variance. Solid lines indicate maximum number of change-point regimes restricted to the maximum number of binary segments of time series.

References

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